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INTERACTIVE SIMULATION OF TECHNOLOGY MANAGEMENT FORESIGHT

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Two of the main foresight challenges are how to handle complexity and uncertainty of evolving technology tracks, which may merge and create new challenges for the management of a company in order to avoid sub- optimization. Complexity refers to the difficulty of identifying and quantifying causal links between a multitude of technology tracks and the degree of interdependency between these tracks. The nature of this challenge can be traced back to several factors such as variable delay periods between causes and effects, increasing synergisms between hitherto separated technology tracks as well as a number of intervening stakeholders at different levels of technology management in an organization. Uncertainty comprises lack of knowledge in addition to variable responses of management to identical technological tracks. The purpose of this paper is to identify and reflect on the obstacles and possibilities of using the combination of narrative and numerical simulation to explore uncertainties and complexities of technology development and implementation in companies. Foresight as a method to develop technology management strategies can hardly be organized as a separated step by step procedure of either qualitative or quantitative processes due to the complexity and uncertainty of the more or less interrelated technology tracks. Accordingly, the foresight approach must allow for interaction between the real-world system and the model builders, for example by using an interacting narrative and numerical simulation approach. This combined simulation approach (CSA) can support strategic decision making by providing different scenarios in combination with computer simulation. CSA is a way to evaluate complexities and risks by addressing possible future events in a more systematically way than is often occurring in companies. The use of CSA makes it possible for management to close the often experienced knowledge and activity gaps between the strategic, tactical and operational levels in a company. The outcome of developing and using CSA is a generic approach that enables the interaction between narrative simulation (scenarios) and numerical simulation. These interactive processes can take place on the strategic, tactical and operational levels of an organization and thus contribute to close the gaps that often exist between these levels. The combined foresight simulation approach is, however, not without practical and epistemological challenges, which will be discussed in this paper, based on the authors' knowledge and practical experience gained by using CSA in a real-world company context. The contribution of this paper to the field is a further development of the existing foresight knowledge about the use of a combined narrative and numerical simulation with the main purpose to provide more consistency between the strategic, tactical and operational plans and activities occurring in a company with special focus on technology management.

Keywords: Strategic foresight, narrative simulation, numerical simulation, decision making.

Introduction

Over the last decades globalization has resulted in a highly competitive business environment. The changing market conditions as well as the evolution of technologies have increased the need for more competitive, dynamic, and robust enterprise strategies, which has been proved as late as with the financial crisis. The need to plan for the future and to be able to adapt to changing circumstances seems to be increasingly important. This puts emphasis on the need for alignment between different functions in the organization so that the organization pursues the same strategic purpose. Methods and processes are needed to manage the strategy development so that well-informed decisions and actions can be made.

Strategy can be developed through the use of many different methods, but typically the methods focus either on narrative perspectives or numerical perspectives. There is a growing concern that the predictive mathematical models conventionally used for understanding the dynamics of business systems are too limiting to serve as tools in future studies, because they cannot reproduce the sudden changes seen in societies. Therefore, it is argued that more robust strategic tools emerge from the interaction between the narrative and numerical contributions (Kljajic, Bernik et al. 2000, Phaal, Farrukh et al. 2010, Baramichai, Zimmers et al. 2007, Kemp-Benedict 2004). Scenario

development in addition to mathematical modelling are both methods that have become increasingly applied as strategic tools in management (Hazy, Millhiser et al. 2007) as they both have different forces in relation to strategy development. A combination of a narrative and numerical approach could possibly strengthen strategy development since two different methods could put highlight on issues neglected if only one type of approach is used. It also puts emphasis on the fact that it is important to view strategy not only as something that is developed on the strategic level, but also as something that is developed, implemented, and used across the strategic, tactical, and operational level.

Technology management foresight is characterized by great uncertainties and complexities, because it can be difficult to predict the affects of investing or not investing in a certain technology (von der Gracht, Vennemann et al. 2010). There are many aspects to consider and the return of an investment can be difficult to determine. This puts great emphasis on the involved stakeholders to investigate and examine different consequences and possibilities of various technologies. These consequences are often rooted in different disciplines, and this makes a transdisciplinary approach interesting since it can draw on the advantages of different methods (Popper 2008). In this paper we will argue that a Combined Simulation Approach (CSA) can be used as a strong tool for the management to examine different strategies and their impact on the strategic, tactical, and operational layers in relation to technology management foresight given that the approach combines two methods rooted in two different paradigmatic positions.

Transdisciplinary Research

Strategic foresight deals with the long term future and is a transdisciplinary approach as the problems dealt with are often complex, ill-defined, dynamic, and intersectoral (Rasmussen, Andersen et al. 2010, Gallati, Wiesmann 2011). There are many definitions of transdisciplinary research and some definitions put more emphasis on the importance of participation of stakeholders:

> *"Transdisciplinary research, in turn, here denotes interdisciplinary cooperation, involving not only scientists but also practitioners from beyond the realm of science (e.g., the users) in the research work" (Pohl 2010).*

Within organizational studies there is a long tradition of recognizing that the contexts within which managerial decisions are made are dynamic and should be acknowledged as an active part of an analysis. Reality is viewed as emergent and in a continuous state of becoming, and research design should include both qualitative and quantitative research methods (Green, Kao et al. 2010). In this paper we view transdisciplinary research as consisting of the essential idea that either- or choices of paradigms should be rejected, and instead the focus should be on "what works" in getting research questions answered (Punch 2009, Johnson, Onwuegbuzie 2004). Transdisciplinary research can be used to observe different layers of a phenomenon since quantitative methods can be used to measure some aspects and qualitative methods some others (Feilzer 2010). The idea of transdisciplinary research is to find a middle ground between philosophical dogmatism and a workable solution (Johnson, Onwuegbuzie 2004). Furthermore, it is found that the involvement of stakeholders in the research work is very important if the workable solution is actually going to be implemented and used, given the fact that the stakeholders possess key information and knowledge related to the research area. Important information can be stored in mental models and not in written form, making it difficult to access. These mental models are complex and subtle and often the basis

of organizational decision making. They incorporate hard quantitative data as well as subjective qualitative data and personal judgmental aspects in relation to a given situation. Therefore, it is important that the process involves the stakeholders in a participatory way that also focuses on the complexity of the system, such as for example uncertainties in relation to data (Gallati, Wiesmann 2011). In relation to strategy making, this is a process that involves strategy formulation in combination with the analysis of the likely evolution of the business environment in order to detect the opportunities and threats that emerge from emerging trends and to deal with them properly (Vecchiato, Roveda 2010). It is a systematic way of managing knowledge, which can be crucial for example for companies in order to gain competitive advantages and cope with the rising challenges of the increasing turbulent business environment (von der Gracht, Vennemann et al. 2010).
There is a wide range of approaches and methodologies to improve future-oriented decision-making for instance scenario analysis, future creating workshop, simulation and modeling, gaming, and road mapping. Furthermore, strategic foresight can be developed from a company perspective focusing on the main players and the forces that originate inside the industry where the firm competes. These activities can be technology trends and competition analysis. It can also be developed from an industry perspective in order to examine the political, economic, ecological, societal, and technological landscapes which surround it. The strategic foresight analysis can be targeted to decision makers within the operational level, the business level and the corporate level at the firm. Typically, the corporate level deals with evaluating the long term attractiveness of different industries and investments. The business level focuses on a specific business area in order to determine which competitive advantage to pursue in the long run. Foresight activities at the operational level focus on a specific organizational unit or project in order to determine how to implement the business strategy successfully. The time horizon expands from short term, which is often related to the operational level, to long term, which is often related to the corporate level (Vecchiato, Roveda 2010). New approaches to foresight introduce a concept of corporate foresight which is based on an open and interactive perspective that focuses on the communication process rather than on methodology (von der Gracht, Vennemann et al. 2010).

The approach in this paper deals with complex problems in the real world. The modeling of this approach is an iterative approach and can refer to the numerical modeling itself but also to different sources of knowledge, such as mental databases/mental models, written databases, and numerical databases. Given that the modeling itself seeks to solve a problem, it has an operational focus. Generality is aimed at by providing transferable insights, models and approaches, and transfer to other contextual settings requires careful validation and adaptation. The integration of stakeholders' knowledge and perspectives and transdiciplinary methods are important from the beginning, because the participatory process has to be carefully structured to enable mutual learning. This also ensures the validation of the modeling process, because the output is constantly debated with the stakeholders (Gallati, Wiesmann 2011).

Strategic Simulation

The term "simulation" is broad and used in different situations. Computer-based simulation has long been used to project the behavior of systems too complex for analytical calculation. Simulation has also been used for many decades to enable human visualization and learn about complex tasks. Traditional strategic analysis can be supplemented with experiential perceptions gained by acting in the future and assessing solution characteristics before investing in the actual development and deployment, and therefore strategic simulation is a way to support strategic thinking (Rouse, Boff

2005). In order to overcome the challenges met when determining which technology track to pursue it is important to uncover and investigate uncertainties plus the complexity of the situation. This can be done in many ways, but we argue for a transdisciplinary approach towards simulation in order to examine the consequences and opportunities of different technological tracks. Strategic simulation is seen as an approach combining two methods, narrative and numerical simulation, and is rooted in two different traditional paradigms. This combination can shed light on areas not uncovered if only using one. The two methods applied will be described in the following along with the Combined Simulation Approach (CSA).

Narrative simulation

In this paper narrative simulation is defined as Interactive Scenario Analysis or Scenario Planning (Lindgren, Bandhold 2009, Van der Heijden 2005, Rasmussen 2011) and is concerned with the development of pictures of what might be as well as how to get there by the means of dialogue between scenario builders and relevant stakeholders. There is no single definition of scenarios, but in this paper a scenario is seen not as a forecast nor a vision, but more as being related to different views of the future to facilitate risk management which is related to strategic planning (Lindgren, Bandhold 2009). Scenarios can help decision makers, planners and stakeholders to get an overview of and deeper insight into the possible outcomes of particular decisions. The special feature of scenario analysis is the long term perspective (1-100 years) on top of the combination of vision-making, story-telling, and strategy formation (Rasmussen 2011). Telling stories about systems helps ensure that stakeholders share a sufficiently wide view to avoid missing vital aspects of problems. Scenarios vary from brief stories to richly structured analyses, but are almost always based on the idea of a sequence of actions. People are very good at reasoning from even quite brief stories, for example they are good at detecting inconsistencies, errors, and threats with little effort, and this is why scenarios are powerful tools. Scenarios are applicable to systems of all types and may be used for different purposes (Alexander 2004). Though scenarios can never be value-free explorations (Kahn, Wiener 1967), they help the users to see the future through various sets of lenses, stretching beyond the ‘conventional wisdom’ or ‘conventional mental map’ (Van der Heijden 2005). Scenario analysis confronts stakeholders with environmental uncertainties by presenting them with several different outlooks on the future and is claimed to be an effective strategic management tool, since it has different functions:

- Evaluation and selection of strategies – Scenarios can provide a framework within which all kind of information and various factors can be more effectively and easily judged by decision-makers.
- Integration of various kinds of future-oriented data – besides quantitative data, scenarios can handle qualitative data.
- Exploration of the future and identification of future possibilities – by exploring the future scenarios can help identify strategic problems and opportunities faced by an organization as well as generate strategic options to deal with them.
- Making stakeholders aware of environmental uncertainties – scenario analysis brings uncertainty into the management process.
- Stretching stakeholders’ mental models – scenarios explicitly confront stakeholders with their own biased viewpoints.

- Triggering and accelerating processes of organizational learning – scenarios are representations of the real world and an area where stakeholders can test hypotheses by doing so also learn faster (Bood, Postma 1997).

Numerical simulation

Numerical simulation is in this paper defined as computer simulation, which is an analytical technique by which a mathematical or logical model of a real system is built in order to draw conclusions about the behavior of the real system. This is done by studying the behavior of the model of which the cause-and-effect relationships are the same as (or very similar to) those of the system under study (Jacobsen 2005). There are many different forms of computer simulation, but the numerical simulation used in this paper refers to simulations, not showing exact results nor the best solution, but showing trends and indicating consequences of a scenario (Jacobsen 2005). A numerical simulation is seen as a representation of a system, and it can give a simplified description of reality or possible future results? It can be used to analyze different solutions, and the idea behind creating a model is to learn about the system. Therefore, it is also important to point out that a model is a representation of reality and not a complete replica of a real system, and simulation building should strictly adhere to including the relevant factors with respect to the needed results and evaluation (Jacobsen 2004, Pidd 2004, Ross 2006, Harrell, Tumay 1995, Chaharbaghi 1991). Numerical simulation consists of two aspects; the simulation tool, such as a simulation language, and the "modeler", who uses the simulation tool to build a model and analyze it. Computer simulation is needed to assist people in capturing the inbuilt dynamics of a feedback model in addition to the complicatedness of a system, for example great dependency between variables and a large amount of variables. It can also be used to reveal unexpected side-effects and counterintuitive behavior. There are many applications possible for numerical simulation, but in this context focus will be on strategy development, which will be further explained in the following. Narrative and numerical simulations have been used separately for many years and each has proven successful within strategic planning. Each of these methods also has its shortcomings that can, however, be overcome by the other approach. Therefore, it is interesting to examine the strength of a combined method in relation to strategy development and implementation.

The combined simulation approach (CSA)

The CSA is the combination of narrative and numerical simulation and it can be used as a tool to support strategic decisions regarding different scenarios. Below a figure illustrating the combined approach can be seen.

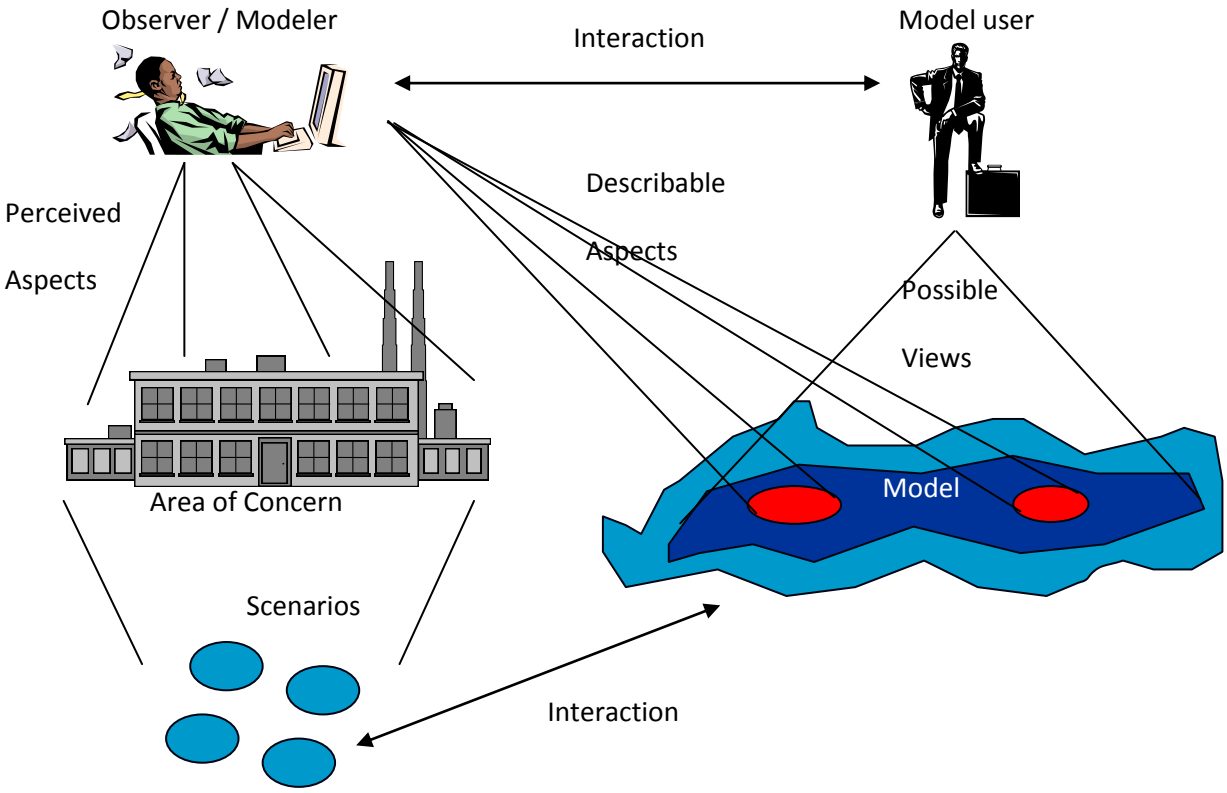

Figure 1: A model of the combination of two methods

Figure 1 shows the combination of narrative and numerical simulation and the elements of combining narrative and numerical simulation. It emphasizes the idea that the two methods, narrative and numerical simulation, should be used in an interactive way as well as the fact that the stakeholders should be involved in the process through interaction with the observer/modeler. The idea of the CSA is not to model all aspects of reality, but to look at certain aspects of a system and then make scenarios based on this area of concern. This means that even though the total system is not replicated it is still the basis of the scenarios and numerical models. Based on the scenarios, the numerical models are developed, and the process of interaction is started with the numerical model because new inspiration to the scenarios and their further development, which again can further develop the numerical models. It is not necessarily all aspects of the scenarios that are numerically modeled, but this is also the strength of the approach, because the narrative simulation can describe aspects that cannot be numerically simulated, and the numerical simulation can clarify the complicatedness and hidden mental models that may exist in the narrative simulation. Furthermore, the combination should enhance creativity by working with uncertainties since the idea is to think in an experimental way and not to reflect the current reality, and also to generate more qualitative output variables in the model, inspired by the narrative simulation. The interaction between the scenarios and the model is important. The idea is to find the narrative points in the numerical simulation, and this is why the interaction between the scenarios and the model is very important.. This suits strategy development because strategy description deals with uncertainty. The combination and interaction of the two methods should enhance the clarification for both sides since the idea of the combination is to start with a scenario and then translate this narrative into a computer model which forces a precision and clarification. This can for example be seen in relation to the where the delimitations in relation to a system should be made. It may be a classic pitfall for

numerical simulation if the whole system is modeled, resulting in a model that is not very usable for the model user and too complicated to apply. However, the combination does not stop there because the important point is the interaction, which again should help clarify uncertainties and ambiguities in the narrative and the scenario. This combination can also enhance creativity because the numerical model offers feedback to the narrative model, which then again can be further developed. The narrative model can then again expand the numerical model and in this way create an iterative process. It can be seen how responsive an outcome is to changes in specific parameters and under certain conditions, and exploring the boundaries of the model can provide valuable insight into both the narrative and the numerical model. This means that many different situations can be researched and adapted as things evolve. One of the forces of the combination is that it opens up for communication: the narrative and numerical models are an opportunity for others to share their insights and critique of the models while they are developed. By making the models explicit, it can be subjected to outside review. The model structure can also be reused by either the model builder or the model user (Hansen 2012, Kemp-Benedict 2004). In this particular case, it means that the stakeholders could follow the work of the scenarios as they evolved over time and give concrete feedback on them, especially the numerical model was also developed in parallel and gave a visual reflection of the scenarios.

The advantage of combining scenarios with numerical simulation is that the method attempts to look ahead and give an input to how the future may look, without being able to predicted it. An important aspect is also that the model is never finished – it can be constantly developed and adjusted to new information. The focus should be on the interaction of the two methods and on using the narrative part to describe the situation and further develop it and on using the numerical part to show the scenarios and further enhance them. Decisions regarding certain aspects in the narrative part can also be carried out by the stakeholders, thus ensuring agreement and concise information. (Loucopoulos 2004, Kljajic, Bernik et al. 2000, Baldwin, Allen et al. 2010). The advantage is that the method can be used to investigate several different possibilities in relation to the choice of technology strategy in order to see what possible consequences different choices will have. Furthermore, the method involves stakeholders on different layers in the organization, thereby shedding light on mental models plus stored information.

Closing the Gap between the Strategic and the Tactical Level in an Organization

The approach of combining the two methods is also a way to focus on the fact that there are several layers in an organization. Given that strategy development and implementation are areas that relate to all of the organizational layers, the intention is that this approach should support a dynamic strategy development and implementation at all three levels and that it can be used to communicate to different levels in the organization.
There are two important dimensions of interaction in the approach:
• The interaction between the numerical and narrative simulation
• The interaction between the researchers and the stakeholders (e.g. managers, practitioners).

This interaction supports the process, and since clarification, creativity, communication and knowledge sharing between researchers and stakeholders takes place through these interactions it is a very important part of the process as also the complexities become clear. At this level a lot of the empirical generation and interpretation takes place because the researchers have to collect knowledge in order to understand the company, the situation, the stakeholders and the mental

models in order to determine and understand the need and complexities. The interaction between the stakeholders and the researchers should take place concurrently in order for the stakeholders to gain ownership of the process and for the approach to be embedded in the company, and therefore this is not illustrated in the figure below. This is also due to the fact that the division between the researcher/modeler and the stakeholders tends to disappear when the stakeholders become more and more part of the development and act more like co-developers. The interaction between the two methods is, however, illustrated below as well as how the process interacts on several layers. It is not possible to see in advance in which direction to take the next step, but below is shown an example of how a process could develop.

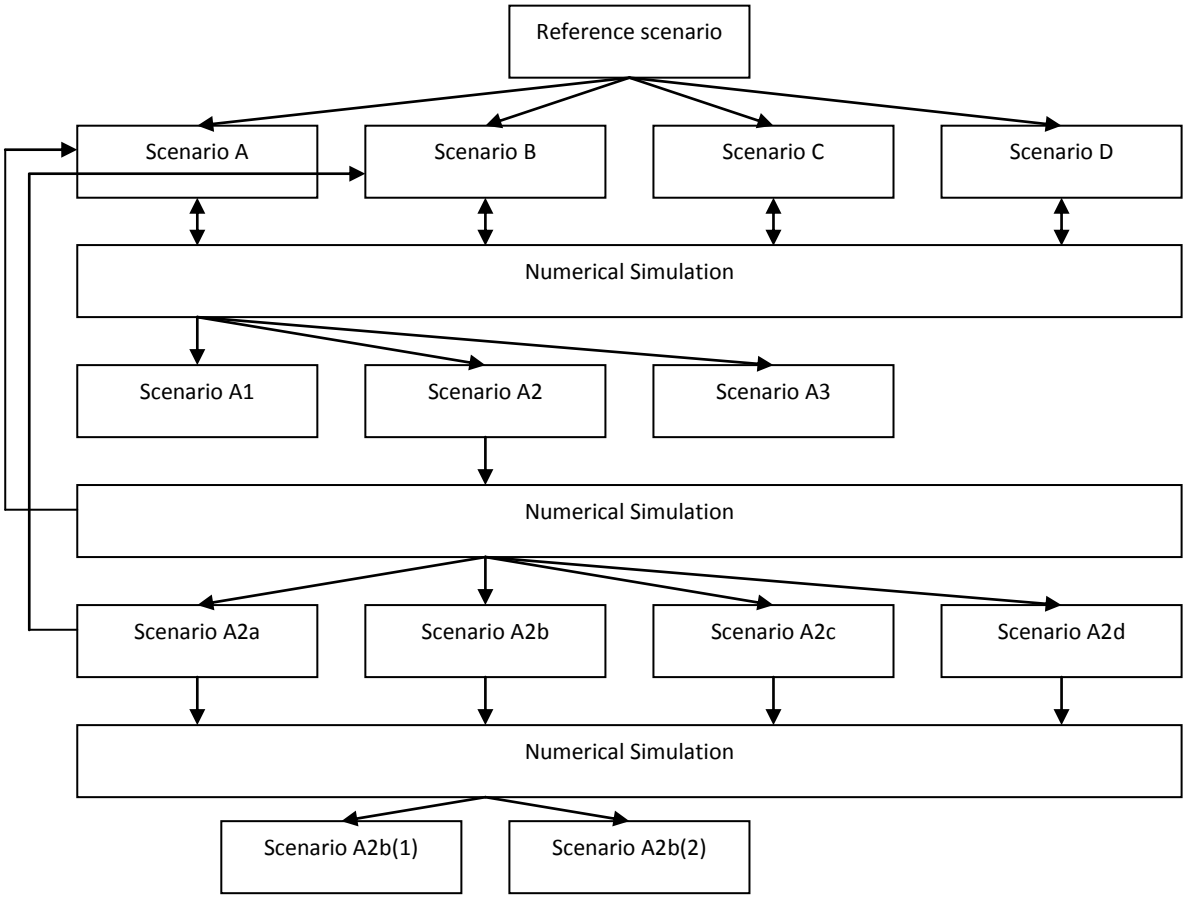

Figure 2: The process

The figure shows that the process started with a reference scenario, which in this process is defined as a scenario describing the current situation in order to clarify what kind of variables are relevant to consider in order to challenge the existing strategy and develop new possible strategies. This is a good starting point because it also helps the researchers and the stakeholders clarify what kind of data is needed for the development of the numerical model. Based on the reference scenario and the interaction between researchers and stakeholders, the different scenarios can be made, e.g. from difficulties experienced in the current situation. This could for example be hidden costs in relation to outsourcing for production companies, bottle necks in the treatment system for hospitals, a wish to reduce fuel costs in the shipping industry. The interaction between the two methods can challenge some point of views as scenarios that appeared to be attractive can be found to be more

expensive than expected when explored more profoundly. During such a process, it can become apparent that certain knowledge is not shared or debated. Here, the method can be an effective tool for putting focus on complexities such as hidden aspects of the strategy in addition to on the different possibilities of how it could be further developed.

The process above shows how the method is a way to move from the strategic level to the operational level and back again. The level of scenario A represents for example the more strategic level, where management is interested in examining the costs related to e.g. the outsourcing strategy in order to determine whether this strategy should be pursued or changed. Based on this, several scenarios for how large a part of the production could be outsourced to for example China and how a larger part of the production could be carried out in-house can be made. Based on these scenarios and numerical simulation of these scenarios, new ideas regarding the fact that the total costs of each scenario result in the level where we find scenario A2. This step leads on to more numerical simulations that bring forward the fact that some costs are hidden and not directly linked to the outsourcing costs in the current setup, even though they have hitherto been included in these costs. This is related to the level of scenario A2b in the process model above. This process makes it possible to simulate different new possible scenarios of the future, which brings the model back to influencing the strategic choices of which outsourcing strategy to follow. This also puts light on the uncertainties and complexities that existing relation to technology management foresight, as for example an outsourcing strategy's cost effectiveness is also dependent on possible new technologies for production and so forth.

An example of the creative aspects of the interaction between the narrative and numerical simulation is that initially a plan can be to pursue scenario A, B, C, and D, but the numerical simulation can form new ideas as to what could be interesting to examine based on the input and output variables and the results. The numerical model can show that some narratives are unattractive or unrealistic to pursue, and then the numerical model becomes the creative basis of further developing the narratives. This was experienced in one of the cases where the method was applied, and where scenario A2 became the reference scenario which showed that it was this scenario that was actually interesting to develop further. The interaction between the two methods was used to explore new and innovative ideas through a combined effort, and it also helped see different viewpoints, taking several scenarios into consideration. Since the models were presented to several persons in a company and used by them as well, the interaction was also a way to incorporate knowledge sharing in the involved departments. This indicates that the interaction between the two methods can be creative in the way that both the scenarios and the numerical simulations can be constantly developed.

The transdisciplinary research is developed through the interaction between the narrative and numerical simulation, and at times it takes place in the researcher's head and is, therefore, not always visible, for example when choosing how to build the model and what to call the variables. Thus, the interaction between the researchers and the stakeholders is very important in order to communicate to the persons that are not involved in the simulation what it demonstrates. This is essential so that the stakeholders experience the creative input that both the narrative and numerical models can give, but also so that the stakeholders develop ownership of the process. Furthermore, the approach is a good way to communicate to people outside the process because the method is both visual and constantly developing. This could be seen in one of the company cases, where the approach was used and where the results were sent directly to the top management who took it into consideration. The method supports a form of knowledge culture, encouraging people to work

together. The above figure shows an example of how the scenarios and numerical models have been developed in depth and across layers in the company because the strategy in the scenarios as well as the numerical models have become more and more detailed and operational. The process involves both researchers and several persons from a company working in different areas and with different opinions. The process can continue iteratively, proving that the transdisciplinary method can successfully be used to assist the strategy process. It is also possible that if the scenarios and simulations are used with a broader user group in the company, and perhaps also outside the company, new ideas could emerge. In the cases where the method has been applied, the management found the results and the method very usable since the method is a tool to make different scenarios and relatively quickly tests several consequences of each scenario before they are carried out in reality. In this way, the method supports the strategy making process and makes it possible to learn without having to face the real costs in a transdisciplinary approach.

Relevant Areas of Combined Simulation

The approach has been used in different cases in relation to strategy development. In one case it was used to support the intended strategy chosen by the management based on a more rational analysis in relation to the choice of distribution strategy. In another case, it was initiated due to the fact that the top management had made a strategy regarding outsourcing that was questioned by one of the departments in the company, as they found that there were several hidden costs not uncovered when planning to outsource. This shows that the approach was both used in a top down approach on top of in a bottom up approach. It is possible to move around in several layers because the method works on the operational, the tactical, and the strategic level – it has shown how these levels are interconnected. Since strategy often in practice combines a centrally made design with a more decentralized adaptation the approach supports this. The method can help in the strategy process as decisions often must be made in the short term in response to long-term goals or proposed changes. Through back casting, scenario analysis and numerical simulation can link long-term transition related to each scenario to the shorter time horizon of current decision makers by making strategy formation plans including goals, various milestones, needed resources and how to obtain them as well as types of opposing interest, inertia and barriers to be taken into consideration.

In relation to the challenges met by companies in relation to technology management foresight, the method could also be a valuable tool since it could be interesting to examine different technological tracks before pursuing them and investing in them. Many industries have to consider possible attractive and profitable technologies and make critical decisions in relation to whether to follow them or not. This means that it can be interesting to pursue different scenarios and the consequences of these scenarios since there can be different elements that can affect the decision. The CSA makes it possible to describe and explore different technological tracks on top of the influence on the business of these tracks. In this way, the method enables a more enlightened decision process. There are different examples of technological tracks with major impact on diverse industries. One example is the fast developing robot technology in relation to production. Robots are expensive to invest in, and it is therefore very interesting to examine in which scenarios it can be relevant to invest in robots for production. Issues in this context could be variables for instance salary costs in different countries, the robot setup and quality. Another area could be the shipping industry where the fuel costs are very high. This makes it interesting to examine whether and when it is profitable in the long run as well as in the short run to build and invest in ships that are energy efficient in relation to the market and the fuel price in addition to ships that can sail on other more

environmentally friendly and cheaper fuels in relation to the possibilities of retrofitting existing ships. A new ship is very expensive to invest in, and it is important to consider all aspects, meaning that it is possible to test different situations and impacts in order to make a well-considered decision. Within the healthcare sector, technology is also developing fast, and it is important for the hospitals, politicians and the pharmaceutical industry to consider which technologies and tracks to follow in order to ensure the best treatment for the population as well as the best profit. There are many possibilities in relation to treatment, medicine, and monitoring, e.g. nanotechnology, tailor-made treatment, bio informatics, robotics and more. The different technologies offer great potential, but it can be difficult to get an overview of the possibilities and consequences of following the different technological tracks. The area of food technologies is also an area where the choice of a technology or a track has to be made with great care. This is due to the fact that there are many aspects in addition to stakeholders to be considered both in relation to ethics, safety, and consumer information. The examples of possible areas of application shown above demonstrate the strength of the method and its application potential across industries. This also opens up for the possibility to further develop and enhance the method.

One of the strengths of the method is that the scenarios and the numerical simulation are developed through close interaction with the stakeholders. This means that the model developer has to keep in mind that there is a possibility of being too heavily influenced by the stakeholders and their opinions. It also implies that it is a time demanding process, meaning that the stakeholders have to use the necessary time for the method to be developed and implemented properly.

Conclusions

Narrative simulation makes it possible to explore paradoxes and opposing interests through alternative imaginations of future situations. Numerical modeling of selected parts of the scenarios can supplement the narrative analysis by carrying out a sensitivity analysis to examine the reaction of certain output variables to a certain change of input values. Since narrative simulation has an important function with regard to involve stakeholders in the scientific and designing activities, narrative simulation can be relevant in addressing many strategic issues in companies such as corporate social strategies, product development, market development, environmental strategies, optimization strategies, cost reduction strategies etc. Narrative simulation facilitates an exploration about possible functional linkages, and numerical simulation can add further knowledge about how much these relationships influence each other. The model developer(s) and model user(s) must interact to focus on interdependent relationships and the functioning between different sub-systems. The expert knowledge that the model user(s) possess can be applied to the narrative and numerical simulations, and through interaction with the model developer(s) it can be integrated into new scenarios and numerical models. The approach can show stakeholders the likely effects of their preferences and viewpoints in a given scenario, and it can be used at many different levels in a company.

The above process model shows that it is possible to operate with both the breadth and the depth of developing strategies. It is possible to develop many possible futures and investigate their potential because the number of scenarios developed is up to the stakeholders and researchers. But it is also possible to go into a very detailed level and examine each scenario in depth in relation to several parameters according to for example technology management foresight. This is also the new part of the method as it is possible to actually reach a much specified level through the disciplinary

approach. This also emphasizes that if a strategy is to encompass and shed light on the various complexities in such a process it should be developed across the different layers of the organization.

Through cases it has been found that the approach is a way to support strategy development, and possibilities for the approach to be used in relation to technology management foresight exist since it makes it possible for decision makers to systematically test several different outputs of possible solutions in order to prepare for future consequences. The method is a way to evaluate risks and address possible unforeseen problems in a methodical way without having to guess or forecast. The two dimensions of interaction support the strategy development as the interactions make it possible to analyze different aspects in relation to strategy within the framework of both narrative and numerical simulation. The interactions also support the implementation of strategy, involving several persons, both employees and stakeholders, in the process. The method appears to work on several levels because it is developed at the operational level but is used to support and improve the strategy development at either the tactical or strategic level. This shows that the method supports strategy implementation since the data needed are found at the operational level through interactions with employees at the operational level. This can support the development and implementation of a new strategy because the persons that will be affected by the strategy have been a part of the process.

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